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Testing QCD with Jet Physics at CDF

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ABSTRACT

We present a variety of jet cross section measurements in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, using 19.5 pb^{-1} of data collected by the Collider Detector at Fermilab during the 1992-93 run of the Fermilab Tevatron. We discuss the impact of these measurements on the status of precision tests of QCD.

1. Introduction

Jet cross section measurements at CDF can be used to determine fundamental QCD quantities, perform a large variety of QCD tests and place unique constraints on the value of the gluon distribution. The improved precision of the data from the 1992-93 run, combined with the recent advances in the theoretical calculations means that precision tests of QCD at the $\pm$ 20% level have become possible. Furthermore, the scope of these tests has been extended to regions of high $|\eta|$, where the boundaries of kinematic phase space can be probed. As a result of these improvements, CDF measurements can now be used in global parton distribution analyses to provide unique constraints on the gluon distributions for $10^{-3} \lesssim x \lesssim .5$

Here, we present preliminary results for the measurements of the inclusive jet cross section, the two-jet differential cross section, and the "same-side" (SS) to "opposite-side" (OS) dijet ratio at $\sqrt{s} = 1800$ GeV. The $19.5 pb^{-1}$ of data were collected by the

CDF Collaboration during the 1992-93 run of the Fermilab Tevatron Collider. Jets are identified by the CDF jet-cone algorithm,[1] using a cone of radius $\sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.7$. to measure the transverse energy, E_T, of a jet.

2. The Inclusive Jet Cross Section

The measurement of the inclusive jet cross section provides a stringent test of QCD over an enormous dynamic range. At high E_T, where the cross section is dominated by quark-quark scattering, deviations from the QCD predictions could signal the presence of quark substructure. At lower E_T's, the cross section is dominated by gluon-gluon scattering, and the measurement provides a leading order (LO) constraint on the gluon distribution. For this analysis, the jets are required lie in the region $0.1 < |\eta| < 0.7$, and the measured jet E_T's are corrected for detector effects.[2] The total systematic uncertainty is around 13% over most of the E_T range, whilst the statistical uncertainty is less than 2% over this range.

In Figs. 1a) and 1b), we show the inclusive jet spectrum on a logarithmic and linear scale respectively. The data are compared with the NLO QCD calculation[3] for MRSD0 parton distributions and a renormalization scale choice of $\mu = E_T/2$. The data and the predictions are in very good agreement over 9 orders of magnitude, with a small excess in the data at both low and high E_T. The renormalization scale dependence and the dependence on the choice of the parton distribution each amount to about a 15% variation in the prediction. Also shown in Fig. 1a) is the prediction for a contact term added to the LO QCD Lagrangian.[4] Comparing the prediction with the data above $E_T > 200$ GeV, we calculate the 95% confidence level on the compositeness parameter to be $\Lambda_c > 1450$ GeV.

3. The Two-Jet Differential Cross Section

The two-jet differential cross section can be used to probe the parton distributions over a wide range of x and to study the behavior of the cross section near the edges of kinematic phase space. For this analysis, only a subset ($\approx 40\%$) of the 1992-93 data has been used. For each event, one jet is required to lie in the region $0.1 < |\eta| < 0.7$, whilst the second jet is required to have an $E_T > 10$ GeV, and to lie in the pseudorapidity slices 0.1–0.7, 0.7–1.2, 1.2–1.6, 1.6–2.0 and 2.0–3.0. Jet energies are corrected to a

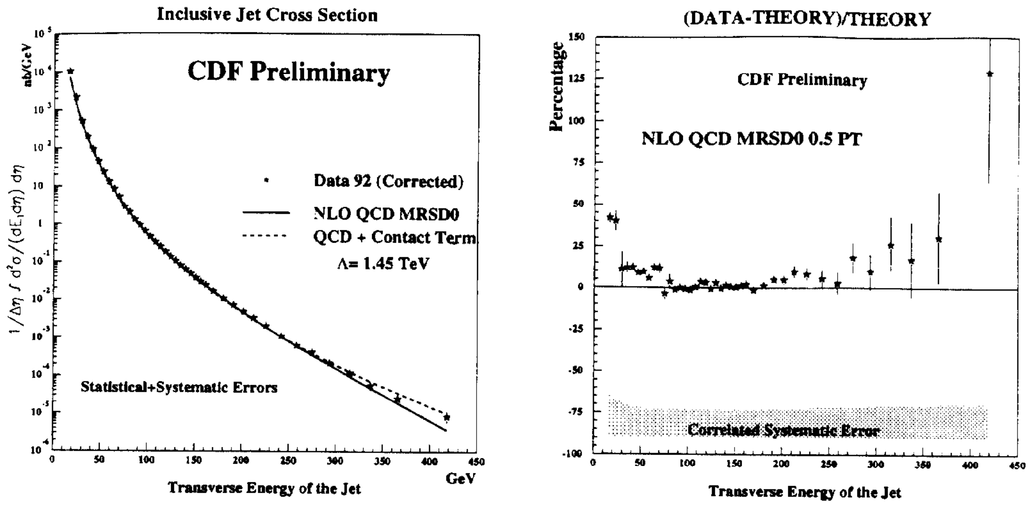

Fig. 1. Comparison of the inclusive jet cross section with NLO QCD on a) logarithmic and b) linear scales. The prediction from LO QCD+contact term is also shown.

common raw energy scale, defined by the central calorimeter. The cross sections have been corrected for detector effects due to energy resolution, but not for those due to η-resolution. The systematic uncertainty varies from about 15% to 30% on the cross section and from 1% to 35% on the ratio of cross sections.

In Fig. 2a) and b), we show the corrected cross sections and cross-section ratios (non-central over central) as a function of E_T for the various slices of $|\eta_2|$. The data are compared to the LO QCD predictions using MT-LO parton distributions and a renormalization scale of $\mu = E_T$. LO QCD provides a reasonable description of the data except for the highest E_T and highest $|\eta_2|$ regions. There, we begin to see the effects of approaching the edges of the kinematic phase space. A recent NLO QCD calculation[5] shows that there is a substantial correction to the LO prediction in this region, thereby bringing the theory into much better agreement with the data.

4. The SS-OS Dijet Ratio

The SS-OS dijet ratio is particularly sensitive to the gluon distribution at small x. The SS (OS) jet cross section is obtained by selecting events with two leading jets whose pseudorapidities have the same absolute values and the same (opposite) signs. The ratio of these cross sections has reduced experimental and theoretical errors. The small-x sensitivity of the ratio is easily understood: At large $|\eta|$ and small E_T, the

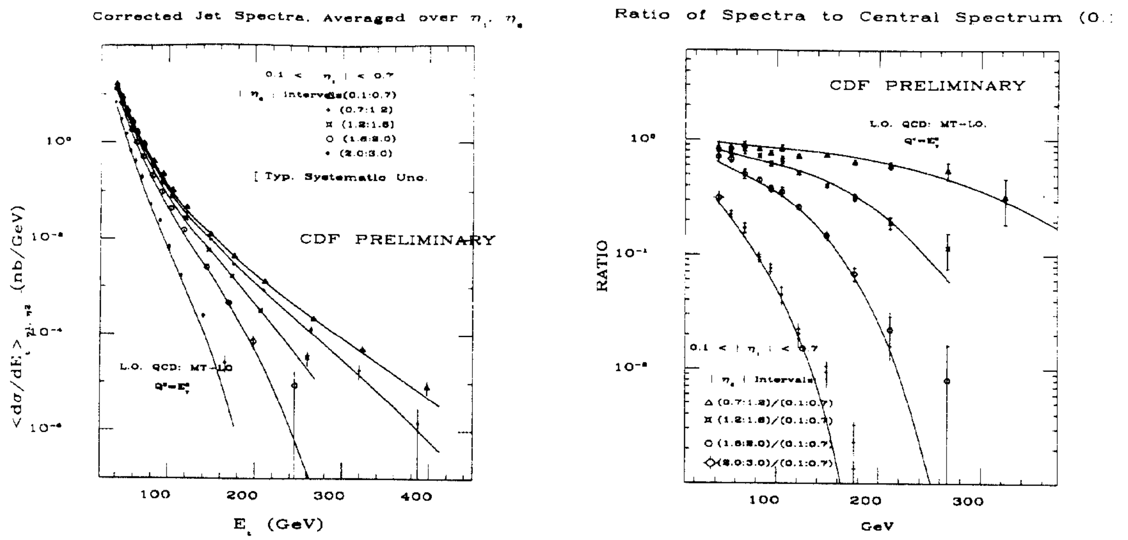

Fig. 2. The a) two-jet cross section and b) ratio of two-jet cross sections for various $|\eta_2|$ slices

SS jet cross section is dominated by gluon-quark scattering, with the quark having a very large x and the gluon having a very small x. On the other hand, the OS jet cross section is sensitive to x values where the parton distributions are relatively well known. The value of the ratio at large η rises faster for a singular gluon distribution than a nonsingular one.

For this analysis, jet energies have been corrected to a common central energy scale. In order to remove some systematic biases, the azimuthal separation between the two leading jets is required to lie in the range $\pi - 0.7$–$\pi + 0.7$. In Fig. 3a)–3d), we show the measured values of the ratio as a function of η_1 for the four E_T regions analysed. They are compared with the predictions of LO QCD for the CTEQ2M and CTEQ2MS parton distribution, where the theoretical predictions have been smeared to take into account the detector effects. These effects, which become important as $|\eta|$ becomes large, are still under study. Overall, the data and the smeared predictions are in qualitative agreement in shape, with some evidence at low E_T supporting the singular gluon hypothesis at small x. At higher E_T's, the ratio provides another test of QCD near the edges of kinematic phase space.

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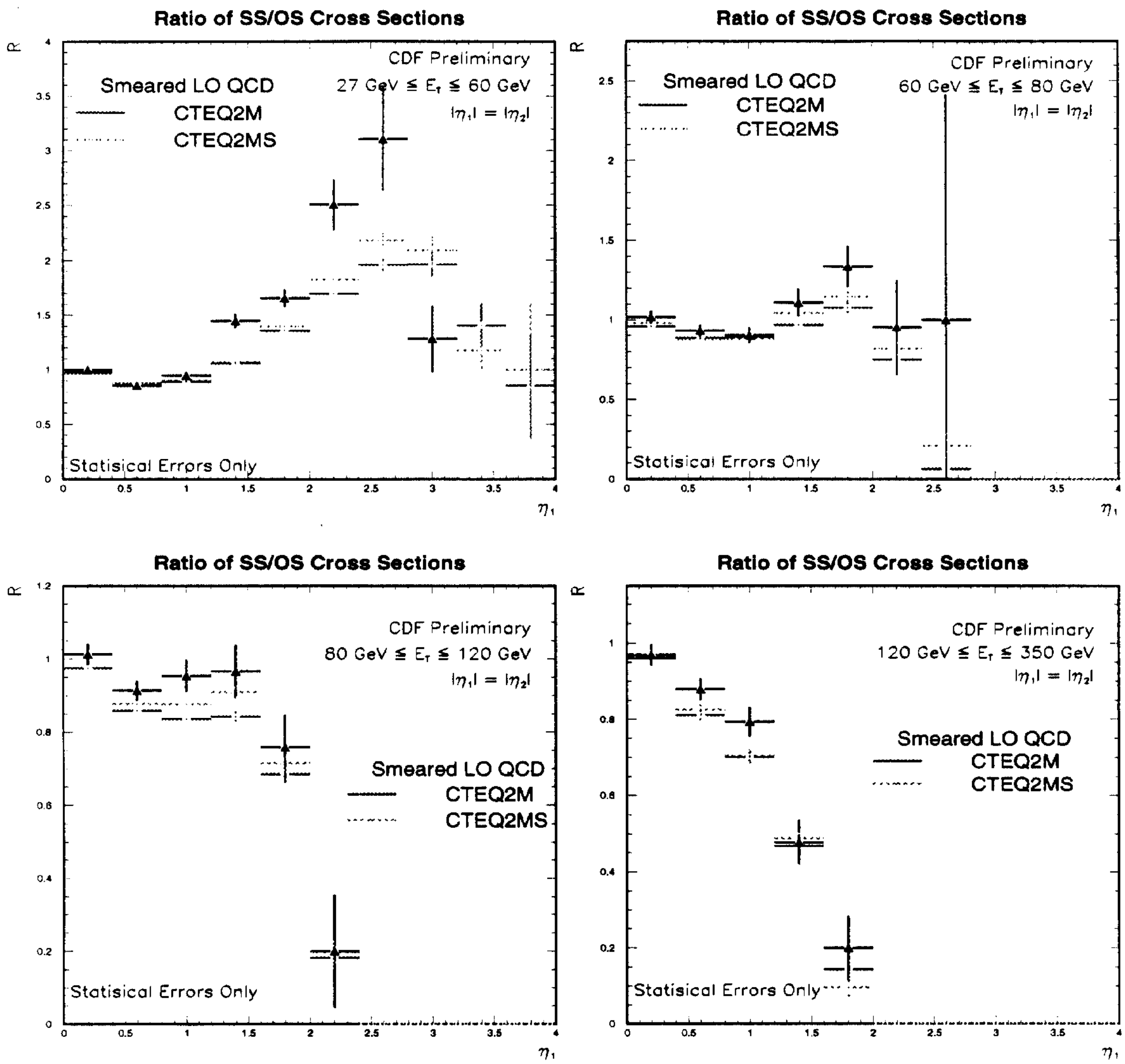

Fig. 3. The measured and simulated values of R as a function of η_1 in the measured E_T ranges a) 27–60 GeV, b) 60–80 GeV, c) 80–120 GeV, and d) 120–350 GeV. Data points are indicated by solid triangles.